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Laser Science & Technology
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Ultrafast Picket Fence Shapes to Enhance NIF Frequency Conversion and Power Balance

The National Ignition Facility (NIF) ignition targets require a high-contrast UV drive pulse shape that varies from a very low power foot at the beginning of the pulse to high peak power near the end. NIF currently converts 1ω to 3ω very efficiently (>80%) for high intensities at the peak, but less efficiently (<15%) during the foot. As a result, the net energy conversion for an ignition pulse is typically only ~50%. We have recently developed a new scheme for NIF pulse shaping which will increase the available 3ω energy by ~40% and improve the power balance among beams by more than a factor of two. The increased energy makes possible new NIF target designs that could have yields exceeding a few 100 MJ.

The picket fence scheme replaces the continuous low-power foot with a sequence of shorter high-intensity "pickets." When averaged over the foot, the pickets supply the requisite low power, yet frequency convert efficiently. However, such schemes had previously been abandoned because the target is not illuminated for long durations between the picket pulses, which adversely affects the target performance. We have extended this concept to the sub-nanosecond regime, where pickets of duration of ~5 to 100 ps are separated by only a few 100 ps. With such a short interval between pickets, we can ensure that the target actually sees continuous illumination. A proposed implementation of this scheme for NIF

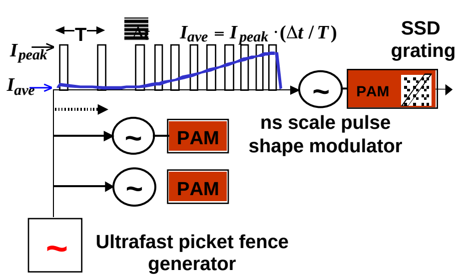
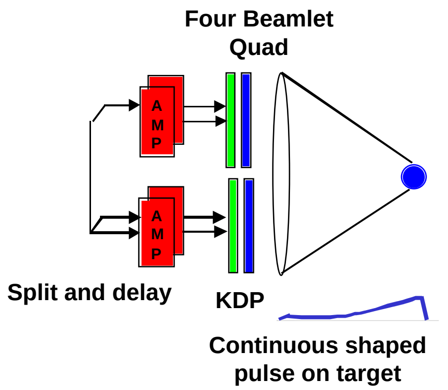


Figure 1: Schematic of proposed ultrafast picket scheme implementation on NIF. A single ultrafast picket generator is used as a source for all the NIF beamlines via 48 preamplifier modules.



(Fig. 1) has the advantage that it only requires the addition of a single modulator box in the master oscillator room. Continuous illumination is achieved by first temporally broadening the pickets at focus by the delay (~60 ps) imposed by the smoothing by spectral dispersion (SSD) grating. In addition, applying a ~60-ps delay sequentially within each of the commonly focused four beamlets of a quad ensures continuous illumination at focus for as much as ~250 ps between pickets.

The limit on how short the picket pulses can be is set by the bandwidth of frequency conversion. This limit is further compounded by self-phase modulation during propagation through the high-power amplifier. Calculation of the efficiency achieved with pickets as short as 20 ps shows that, in spite of the limitations, one sees a large improvement in conversion during the foot (from ~15% to 50%). The resulting net conversion efficiency of 3ω energy to target is improved from ~50% to ~70%.

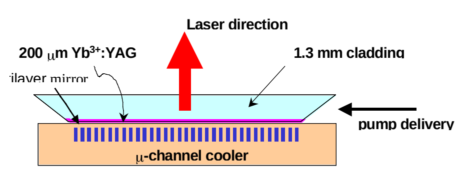
An unexpected benefit of this scheme is vastly improved power balance at 3ω. The conversion efficiency of the pickets saturates at much lower intensity owing to the aforementioned bandwidth and nonlinear effects. As a result, in the foot the 1ω imbalance that is normally increased by a factor of ~3 upon conversion to 3ω can instead be reduced upon conversion. A calculation of the resulting effect on the 3ω power balance (Fig. 2) shows a large improvement. Thus, this scheme also provides a large margin for the challenging NIF power balance specifications, and is an attractive method to achieve the ~4% balance required for direct drive.

—Josh Rothenberg

First Light Generated from Yb: YAG/YAG Composite Thin-Disk Laser

We are working on a composite thin-disk laser that can be scaled to high brightness and high power for tactical weapons and other high-average-power applications. The key optical component is a diffusion-bonded composite comprised of a thin gain medium and thicker cladding that is robust and can be operated under high-average-power laser conditions. In contrast to high-power rod or slab lasers, a thin-disk laser with one-dimensional cooling geometry can be scaled gracefully to very high average power.

We have successfully demonstrated "first laser light" from thin-disk laser in the lab. During this experiment, optical pumping of the 1.5-mm- thick composite Yb:YAG/YAG laser element is achieved using a radiance-conditioned laser diode array and a lens duct. The gain medium is 200 μm thick and thermally contacted with 4μm of indium solder to a cooler. We have achieved a laser power of 260 W at low duty factor and have used this data to anchor our laser modeling codes. The Yb:YAG/YAG composite gain element was fabricated by Onyx optics using diffusion bonding. Strong excitation and cooling of the thin laser gain medium was demonstrated and found to be consistent with our ray-trace model predictions. The efficacy of the heat removal using our first-generation cooler was tested by the prototype. Calorimetric data (coolant flow rate and temperature rise) under continuous diode pumping showed that we reached a heat dessipation rate of 1.1 kW/cm^2 at the surface of the cooler. The maximum heat flux attained was very close to that predicted in our design calculations. Based on our understanding of the thin-slab design, we believe that multi-kilowatt output can be achieved from a single thin-disk



—Luis Zapata

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